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The Effects of meteorological variables on ambulance attendance for cardiovascular diseases in Rasht, Iran

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The Effects of meteorological variables on ambulance attendance for cardiovascular diseases in Rasht, Iran

Abstract

Climate change has a devastating effect on human societies, including their economic, cultural and health conditions. Our objective was to investigate the association between meteorological variables and ambulance attendance in the event of cardiovascular diseases using time-series analyses.

We used a time series analysis to investigate the relationship between meteorological variables and ambulance attendance in the event of cardiovascular diseases from 2010 to 2015. To examine the effect of high temperatures on ambulance attendance, we investigated the relative risk of the daily volume of high temperature attendance, the 99th temperature percentile compared to the 75th temperature percentile. Upon examining the effect of cold temperatures on ambulance attendance, or the relative risk of the daily volume of attendance with low temperatures, the 1st temperature percentile compared to the 25th temperature percentile.

In 1,826 days, from March, 21, 2010 to March, 19, 2015, there were 7051 emergency calls for cardiovascular diseases. Significant variations were identified in the monthly (P < 0.001) and seasonal (P < 0.001) distributions. The highest seasonal incidence occurred in the winter and lowest was observed in the summer. With regard to association between cold temperature and calls for ambulance attendance in the event of cardiovascular diseases according to lag days, our findings showed a significant increase in lag 7 ((RR, 1.026; 95% CI, 1.003 to 1.050), lag 8 (RR, 1.023; 95% CI, 1.005to 1.041) and lag 9 (RR, 1.019; 95% CI, 1.002 to 1.036) respectively. These results suggest that the demand for an ambulance for cardiovascular diseases was higher in the cold weather and that humidity can increase this demand in the warm seasons.

Key Words: Ambulance attendance, Cardiovascular, Meteorological variables, Temperature

Introduction

Climate change has a devastating effect on human societies, including their economic, cultural and health conditions. Climate change affects human health and well-being through extreme weather conditions, wildfires, decreased air quality, insect-borne diseases, food, and water (McMichael, 2013; Moghadamnia et al., 2018a). Climate change, especially extreme conditions, can disrupt health care access via evacuation, destruction of assets, population displacement, and damage to or loss of infrastructure.(Richardson K et al., 2009; Rizzo-Pelley, 2014). Extreme event weather, such as heat waves and cold spells, are associated with increased cardiovascular, respiratory, and renal diseases leading to mortality and morbidity (Wang and Lin, 2014). Acute myocardial infarction (AMI) is one of the most common causes of death for patients with cardiovascular diseases (CVD) characterized by an acute onset of myocardial injury resulting in myocardial death (Brunner LS et al., 2010; Liang et al., 2008). Many studies have focused on AMI, which is one of the most important cardiovascular diseases requiring emergency medical service (Ghiasmand et al., 2017; Wichmann et al., 2011). A number of meteorological studies have examined the relationship between meteorological variables and the occurrence of cardiovascular and respiratory diseases and ambulance calls for providing health care in these patients (Vencloviene et al., 2015; Wong and Lai, 2012). It have been proven that the hot and cold temperatures have an adverse effect on the risk of myocardial infarction. (Bhaskaran et al., 2009). The significant inverse relation between temperatures and ACS incidence suggests that cold may play an important role in the incidence of ACS (Ezekowitz et al., 2013). Several possible physiological changes have been proposed to explain the seasonal variation of ACS incidence, including changes in clotting mechanisms, lipid levels, and blood pressure (Li et al., 2011). Moreover, exposure to high temperature could increase plasma viscosity and cholesterol levels in serum, resulting in higher blood pressure (Lin et al., 2013a). Some studies have reported greater cold-related mortality than heat-related mortality; in addition, heat wave effects appear to last for a few days at most, whereas effects of cold spells may persist for up to 2 months (Goggins et al., 2013; Moghadamnia et al., 2017; Xie et al., 2012). Nevertheless, findings of Grjibovski et al suggested that no association was found between the daily counts of deaths from ischemic heart disease or

cerebrovascular diseases and temperature in Astana, Kazakhstan (Grjibovski et al., 2012). A number of studies have reported a strong relationship between ambient temperature and emergency admissions by ambulance for respiratory disease (Turner et al., 2012). However, the association between meteorological variables and emergency ambulance calls for cardiovascular diseases has not been well-evaluated in the Iranian population. Our objective was to investigate the association between meteorological variables and ambulance attendance in cardiovascular diseases using time-series analyses.

Methods

This study was conducted in Rasht, the biggest city located in northern Iran. Rasht has a humid subtropical climate with relatively high temperatures in summer and mild winters, with occasional winter storms with rainfall coming from convectional thunderstorm activities. The municipality has a population of one million people who live in an area of 180 km2 at the latitude of 37.2682° and the longitude of 49.5891° (figure 1). The Gilak are an Iranian people native to the northern Iranian province of Guilan and are one of the main ethnic groups residing in the northern parts of Iran, including Rasht. The Gilak live both alongside the Alborz Mountains and in the surrounding plains. The population of Gilaks is estimated at 2.5 million (2016 census).

Ambulance attendance data

The ambulance attendance data were provided by the Center for Medical Emergency and Incident Management of Guilan province, the main provider of out-of-hospital emergency care and ambulance transport in Guilan. The variables extracted from each nameless attendance record included the date of attendance, sex, and age of the patient. A specific diagnosis was made by a pre-hospital medical service provider according to health assessment and the results of the diagnosis recorded using a specific coding system from 2010 to 2015. In this study, we calculated the daily number of ambulance attendances for groups of health assessment codes related to cardiovascular diseases.

Meteorological data

The daily data of weather conditions included the minimum (C°), maximum (C°) and mean of temperature, dew point temperature, barometric pressure (bar), humidity (%), the wind speed (m/s) and precipitation (mm) and were gathered over the 5-year period

from the Rasht meteorological center. Rasht has 3 weather stations. Due to the small size of the urban area and non-significant differences in the data of these 3 stations, we used the data of the Rasht airport station.

We recruited apparent temperature as an exposure variable that combined heat and high humidity, which is a composite index of human discomfort. This index characterizes the physiological experience better than ambient temperature because it captures the physiological experience better than temperature alone and has been used in other studies assessing morbidity and mortality (Stafoggia et al., 2006; Zanobetti A and Schwartz J, 2008). The apparent temperature was calculated with the following formula:

$$AT = -2.653 + (0.994 \times Ta) + (0.0153 \times Td2)$$

In this formula, Ta is air temperature and Td is dew point temperature. We used the daily mean values of weather variables on the day of the ambulance call.

Data analysis

We used a time series regression to assess the relationship between meteorological variables and ambulance attendance in CVDs. Previous studies have reported that the association between variables such as temperature and morbidity is non-linear and might be delayed in time. The risk of hospitalization not only will increase on the same day but also for several following days (Gasparrini et al., 2010; Giang et al., 2014; Guo et al., 2012; Huang et al., 2014).

These datasets — meteorological variables and ambulance attendance — were merged together. Spearman's correlation coefficients were used for exploring the monotonic relation between daily ambulance attendance and meteorological variables. A quasi-Poisson regression model combined with a DLNM was used to assess the impacts of daily meteorological variables on ambulance attendance on different lag days (Yang et al., 2015). The long-term and seasonal trends of daily mortality were controlled by using a natural cubic spline of time with 7 degrees of freedom (df) per year, the day of week and holiday. In addition to the overall effects of meteorological variables on the need for ambulance attendances in cardiovascular diseases, we analyzed the association between weather conditions and daily ambulance calls during the cold period (October–April) and

the warm period (May–September) separately. To examine the effect of high temperatures on ambulance attendance, we investigated the relative risk of the daily volume of high temperature attendance, the 99th temperature percentile compared to the 75th temperature percentile. Upon examining the effect of cold temperatures on ambulance attendance, or the relative risk of the daily volume of attendance with low temperatures, the 1st temperature percentile compared to the 25th temperature percentile. To assess possible delayed associations, we examined the impact of apparent temperature for up to 20 days. All data analyses were performed using the R software (version 3.3.3). The 'dlnm' package was used to fit the distributed lag non-linear model. The Quasi-Poisson regression model was the common statistical model for count response (ambulance attendance) and for handling over-dispersion. Also, the distributed lag non-linear model (DLNM) was used to examine non-linear and lag effects of daily meteorological variables on ambulance attendance. A time series regression model with a combination of the Quasi-Poisson regression model and the distributed lag non-linear model was used to take into account both the over dispersion of the count response and the non-linear and lag effects of time-varying covariates.

All statistical tests were two-tailed and $p<0.05$ was considered statistically significant. Sensitivity analysis was performed to test the robustness of our main results by changing the location of knots for exposure: response, and 5–20 lag days for apparent temperature, 6–10 df for time trend, 3–10 df for relative humidity. This research was approved by the Ethics Committee of Guilan University of Medical Sciences (code: IR.GUMS. REC.1395.85).

Results

In 1,826 days, from March 21, 2010 to March 19, 2015, there were 7,051 emergency calls for ambulance attendance due to cardiovascular diseases. The descriptive characteristics of daily meteorological variables for cold and warm seasons during the study period are shown in Table 1. Significant differences between mean values of daily apparent temperature, barometric pressure, relative humidity and wind speed in cold and warm seasons were observed. Figure 1 shows the distribution of cardiovascular attendance events and daily average apparent temperature. Figure 2 shows the existence of a roughly

similar pattern in meteorological variables during the study. Also, the trend of ambulance attendance shows an increase in requests for ambulance attendance for cardiovascular diseases in the recent years. The calls for attendance ranged from 0 to 18 (4.54 ± 2.46) and 0 to 11 (3.83 ± 2.18) in cold and hot seasons, respectively. Significant variations were seen in the monthly ($P < .001$) and seasonal ($P < .001$) distributions. The highest seasonal incidences occurred in the winter and the lowest in the summer. Figure 3 shows an association of monthly apparent temperatures and daily volume of ambulance attendance in the warm period (May–September), versus the cold period (October–April). Monthly cases reached the peak and the nadir in December and August, respectively (figure 3).

A significant relationship ($p=0.01$) was found between the humidity percentage and the number of calls for ambulance attendance in the warm season; the increase in the calls was associated with elevated humidity.

Spearman’s rank correlation coefficients were used to evaluate the relationship of each two of apparent temperature, barometric pressure, humidity, wind speed, and calls for ambulance attendance in cardiovascular cases (Table 2). Our findings showed a negative correlation between apparent temperature and ambulance attendance and also the positive correlation of daily average barometric pressure, wind speed and humidity with the calls for attendance.

With regard to the association between the cold temperatures and calls for attendance in cardiovascular diseases in lag days, our findings showed in lag (0- 1) and lag (0-2) that the call for ambulance decreased (RR, 0.91; 95% CI, 0.87 to 0.97) and (RR, 0.93; 95% CI, 0.86 to 0.99), respectively (table 3, 4). On the other hand, a significant increase was found in lag 7 ((RR, 1.026; 95% CI, 1.003 to 1.050), lag 8 (RR, 1.023; 95% CI, 1.005to 1.041), and lag 9 (RR, 1.019; 95% CI, 1.002 to 1.036) (figure 4).

Sensitivity analysis was performed in this study for modelling choices. Estimates of the effect of ACS admission due to temperature were similar when we changed the places of knots for temperature–admission relation and when 5–20 lag days for apparent temperature, 6–10 df for time trend and 3–10 df for relative humidity.

Discussion

The aim of this study was to assess the association between meteorological variables and ambulance attendance in cardiovascular diseases using time-series analyses. The results of this study showed that more emergency calls for cardiovascular diseases were registered during the cold seasons, which is aligned with previous studies (Bhaskaran et al., 2009; Vencloviene et al., 2015; Wolf et al., 2009). Exposure to cold temperature is associated with physiological changes that include: increased plasma viscosity and blood pressure (Eldwood et al., 1993; Marchant et al., 1994), platelet aggregation, red blood cell counts, cholesterol levels and fibrinogen of plasma (Kawahara et al., 1989; Mercer, 2003). In addition, low temperatures affect the body’s circulatory system. In cold weather, peripheral circulation decreased and an accumulation of blood in central organs occurred. The cold temperature had a delayed effect and was found to generally occur 7-9 days following exposure. This is consistent with previous studies in which the temperature variability had a delayed effect on health. The study conducted by Huang et al showed that the effect of the cold temperatures had a long lag period of 10–25 days, while the hot temperatures had a short lag period of only 1–3 days (Huang et al., 2014). Several recent studies reported that the cold days have a longer lag effect on cardiovascular morbidity and mortality compared to hot days (Lin et al., 2013b; Moghadamnia et al., 2018b). Generally, cold temperatures will trigger acute coronary syndromes such as acute myocardial infarction (Hong et al., 2003). The ability of the individual to adapt to the meteorological variable is unique. Some individuals can adapt without any problem, while in other individuals the adaptation ability is exhausted. The findings of the study in Rasht showed a significant seasonal variation of the daily volume of calls for ambulance attendance, which happened more in winter. This is consistent with several other studies showing an association between seasonality and a demand for ambulance services (Otsuki et al., 2016; Vencloviene et al., 2015; Wong and Lai, 2012).

In relation to the interaction of climate variables such as relative humidity, air pressure and wind speed in cold and warm seasons on the daily volume of ambulance attendance for CVD, our finding showed that only by increasing the relative humidity in the warm

season would calls for an ambulance increase. Vencloviene et al reported that an increase in relative humidity, atmospheric pressure, and wind speed during the warm season caused an increase in the daily volume of ambulance calls for ACS (Vencloviene et al., 2015). Atmospheric pressure changes cause an alteration in the pressure on skin veins, which result in blood pressure changes. The pressure on existing atherosclerotic plaques also changes, resulting in an increased risk of plaque rupture. A sudden drop in temperature leads to an increase in hemostatic and inflammatory factor levels, resulting in a hypercoagulable state. In cold atmospheric conditions, the levels of hemoglobin, hematocrit, red blood cell, thrombocyte, C-reactive protein, plasminogen activator, and factor VII increase, whereas the antiplasmin level decreases (Rivolier, 1974; Schäuble et al., 2012).

The results showed an inverse relationship between apparent temperature and the need for ambulances, so that with increasing temperature the need for ambulances decreased. This is consistent with the findings of Vencloviene et al(Vencloviene et al., 2015), who reported more calls during the cold period (October–April), whereas during the warm period (May– September) the mean value of emergency calls per day was significantly lower.

Our findings have several clinical efficiencies. In light of our results, we can conclude that cold temperatures can be considered a minor cardiovascular risk factor. To achieve better CVD control among susceptible populations in the future, we must take into account the adverse effects of extreme weather conditions and use new preventive and adaptive strategies in order to prevent the negative cardiovascular effects from the meteorological hazard. More health education planning is needed to increase awareness of the role of a meteorological variable in order to advance prevention culture. Individuals who are vulnerable to weather conditions should not be exposed to adverse weather conditions. Special attention must be paid to proper cold-weather attire, as well as heating. Establishing suitable biometeorological forecast systems and early warning systems are essential prevention strategies in reducing adverse effects of the meteorological hazard.

Limitations

Limitations of this study include the assignment of patients to cardiovascular diseases, which was done by an emergency medical technician. This may affect a number of CVD patients; however, most CVDs are clinically diagnosed based on their medical history, physical examination, and electrocardiograms. Another limitation of this study is an epidemic of many infectious diseases, such as influenza, which could not be controlled.

Conclusion

The present study showed that the daily volume of ambulance calls for CVD was related to specific weather conditions. These results suggest that the demand for ambulances for CVD was higher in cold weather and that humidity can increase this demand in the warm season. The research has significant practical and policy implications. A better understanding of the association between weather variables and patterns of calls for ambulance attendance will enable us to forecast the demand for emergency ambulance services.

Even though our findings showed an increase in the demand for ambulance services in cold weather, hot weather with humidity may exert more significant impacts given the global trend of rising temperatures.

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Conflicts of interest

There are no conflicts of interest.

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Figure 1 Map of Rasht

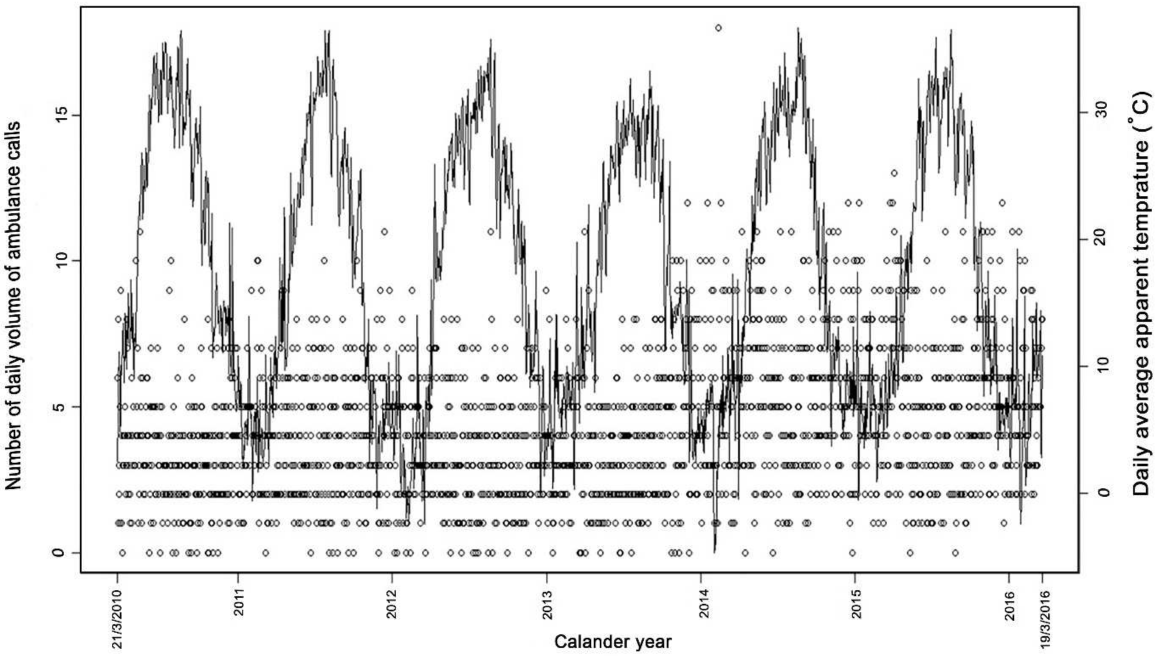

Fig. 2 Apparent temperature (line) and ambulance calls for CVD (circles)

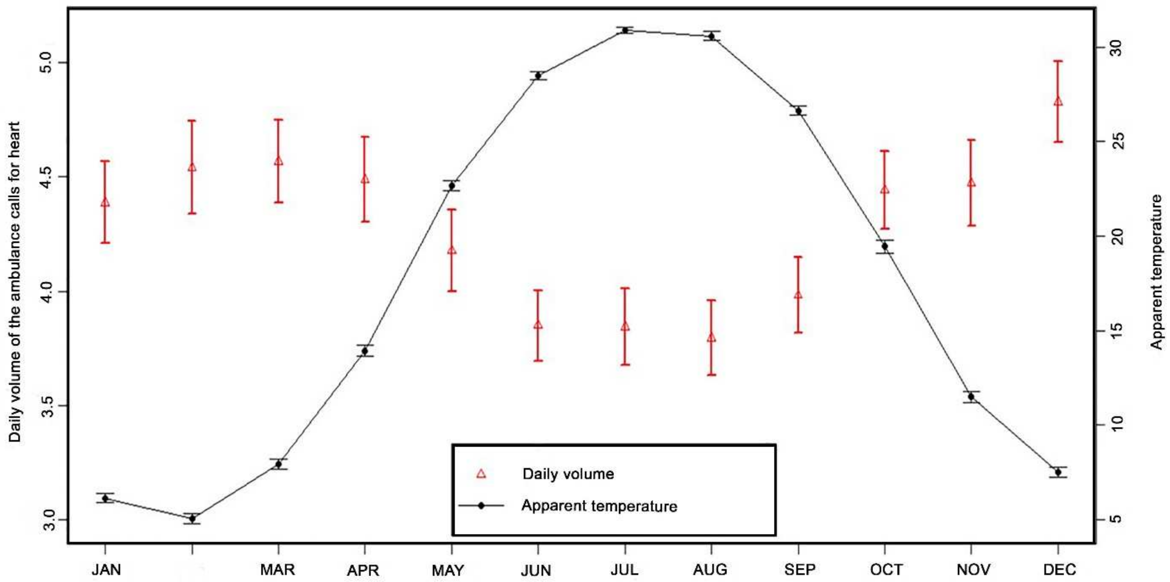

Fig. 3 Monthly volume of ambulance calls and temperature variation

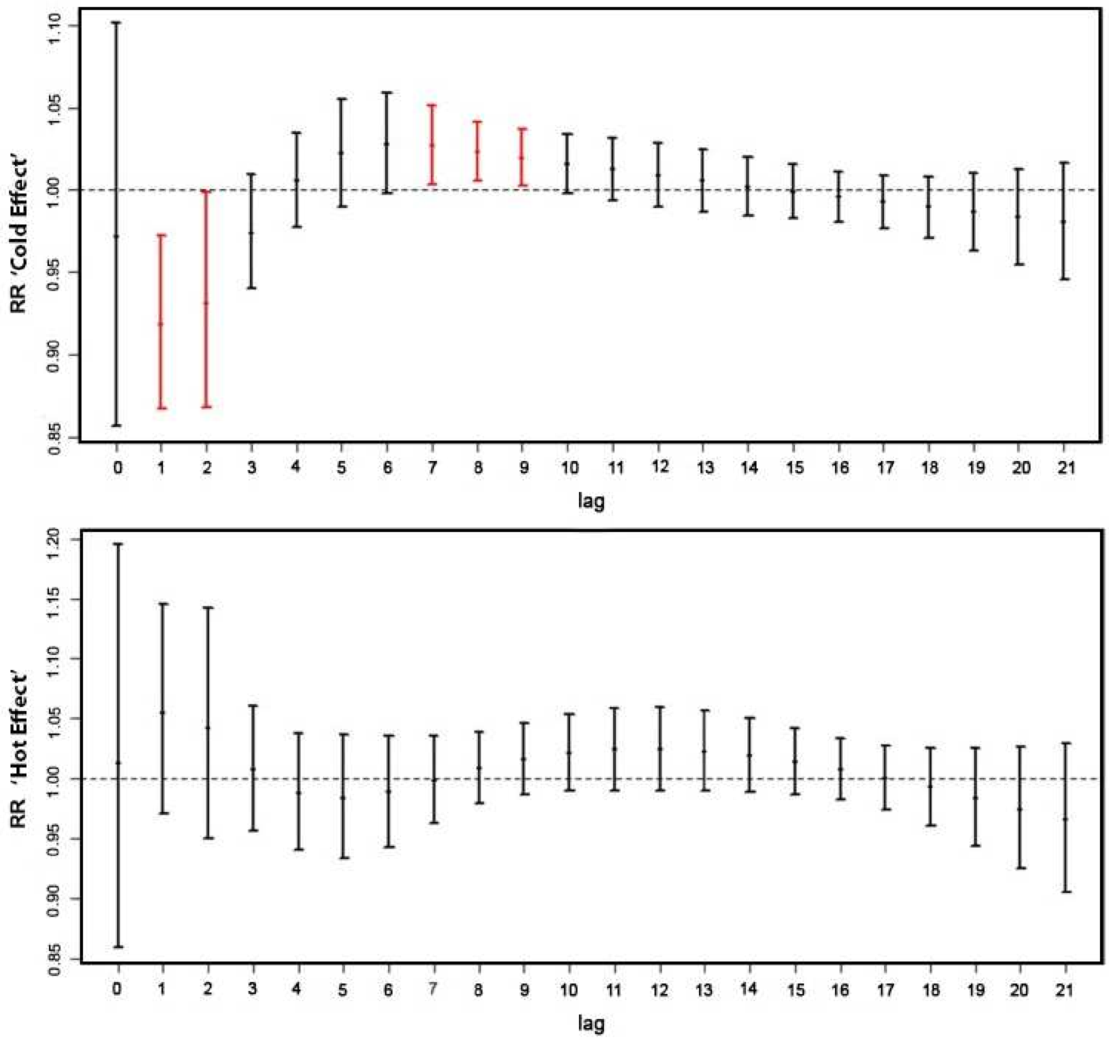

Fig 4 Relative risks of calls for ambulance for cardiovascular disease in lag days

Table 1. Descriptive characteristics of meteorological variables

Variable	The whole period		Cold season	Heat season	p-value
	Range	Mean(SD)	Mean(SD)		
Apparent Temperature (°C)	-4.1-39.4	17.64(10.24)	9.66(6.18)	30.01(3.05)	<0.001
Relative Humidity (%)	25.24-100	82.98(10.22)	86.5(10.59)	76.86(8.21)	<0.001
Barometric Pressure (hPa)	904.2-1043	1017.24(7.67)	1021.43(7.67)	1010.85(3.77)	<0.001
Wind Speed (km/h)	0-9	1.68(0.9)	1.73(1.1)	1.62(0.62)	0.012

Table 2 Correlation between calls for ambulances and weather variables

Weather variables	Spearman's rank correlation of calls for ambulances in CVD
Average apparent temperature	-.099**
Wind speed	.047*
Barometric pressure	.035
Humidity	.044*

**** Correlation is significant at the 0.01 level (2-tailed).**

*** Correlation is significant at the 0.05 level (2-tailed).**

Table 3: The cumulative effects of cold temperature on ambulance attendance

Lag	All cases (RR, CI)	Males(RR, CI)	Females(RR, CI)	≤64 years(RR, CI)	≥65 years(RR, CI)
0	0.97(0.85-1.1)	0.95 (0.89-1.05)	0.98 (0.91-1.04)	0.98 (0.96-1.00)	0.96 (0.89-1.04)
0-1	0.92(0.86-0.97)	0.97(0.94-1.01)	0.88(0.82-1.01)	0.92 (0.70-1.21)	0.93 (0.74-1.17)
0-2	0.93(0.87-0.99)	0.93 (0.72-1.19)	0.93 (0.72-1.19)	0.94 (0.76-1.15)	0.94 (0.76-1.16)
0-3	0.98(0.94-1.01)	0.99 (0.97-1.01)	0.97 (0.95-1.00)	0.98 (0.87-1.10)	0.99 (0.96-1.02)
0-7	1.03(1.01-1.06)	0.99 (0.96-1.01)	1.03 (0.99-1.06)	1.01 (0.99-1.03)	1.02 (0.99-1.06)
0-14	1.00(0.98-1.02)	0.99 (0.97-1.01)	1.01(0.99-1.02)	1.01(0.99-1.03)	0.99(0.93-1.05)
0-20	0.98(0.96-1.02)	0.97(0.95-1.02)	0.99(0.97-1.02)	0.97 (0.84-1.11)	0.99(0.94-1.04)

**RR (Relative Risk)

**CI (Confidence Interval)

Table 4: The cumulative effects of hot temperature on ambulance attendance

Lag	All cases(RR, CI)	Males(RR, CI)	Females(RR, CI)	≤64 years(RR, CI)	≥65 years(RR, CI)
0	1.02(0.85-1.20)	1.03 (0.86-1.19)	1.01(0.85-1.20)	1.02 (0.88-1.20)	1.01(0.85-1.20)
0-1	1.06(0.97-1.14)	1.05(0.95-1.15)	1.06 (0.99-1.13)	1.05(0.95-1.15)	1.06 (0.99-1.13)
0-2	1.04(0.96-1.13)	1.04(0.95-1.14)	1.04 (0.97-1.14)	1.05(0.96-1.16)	1.03 (0.99-1.14)
0-3	1.01(0.96-1.06)	1.00 (0.94-1.07)	1.00 (0.94-1.05)	1.01 (0.95-1.07)	1.00 (0.94-1.05)
0-7	0.99(0.97-1.04)	0.99 (0.96-1.04)	0.98 (0.95-1.03)	1.00 (0.99-1.04)	0.99 (0.96-1.05)
0-14	1.03(0.98-1.06)	1.04(0.97-1.07)	1.04 (0.97-1.09)	1.03(0.98-1.07)	1.05 (0.98-1.10)
0-20	0.97(0.93-1.03)	0.97 (0.91-1.04)	0.98 (0.92-1.03)	0.98 (0.93-1.04)	0.99(0.93-1.04)

**RR (Relative Risk)

**CI (Confidence Interval)

The results showed an inverse relationship between apparent temperature and the need for ambulances so that with increasing temperature need to ambulance decreased. The results of this study showed that more emergency calls for cardiovascular diseases were registered during the cold seasons. The cold temperature had delayed effect and was found to generally occur 7-9 days following exposure. Findings of the study showed a significant seasonal variation of the daily volume of call for ambulance attendance which happened more in winter. our finding shows only by increasing the relative humidity in the warm season, calls for an ambulance increases.